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The NESTORE e-Coach: Accompanying Older Adults through a Personalized Pathway to Wellbeing

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ABSTRACT

This paper describes the NESTORE e-coaching strategy and system architecture and its unique approach to support older adults to achieve a healthier lifestyle. The novelty of the NESTORE project is the definition of a multi-domain personalized pathway where the e-coach accompany the user throughout different structured and non-structured coaching activities and recommendations. The NESTORE e-Coach is the result of a highly multidisciplinary EU project, granted under the call SC1-PM-15-2017.

CCS CONCEPTS

• **Social and professional topics ~ Seniors** • Applied computing ~ Consumer health

KEYWORDS

Older adults; virtual coach, healthy lifestyles, pathway; wellbeing.

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1 Introduction

Nowadays, healthy aging systems and services to prevent decline or support wellbeing in the elderly is a major target in the European society. NESTORE is a European project funded by EC aiming at developing novel solutions for healthy ageing leveraging mobile technologies as a common and distributed platform to provide coaching services [1]. In particular, NESTORE tackles to assist older adults by developing an innovative, multi-dimensional, personalized coaching system to support healthy ageing in four wellbeing domains: physical and physiological functioning, nutrition, cognitive functioning, as well as social interactions.

The NESTORE system acts as an integrated architecture including Apps, wearable and environmental sensors to collect users' data, which is then passed on to a smart Decision Support System (DSS). The DSS measures the status of people in the five wellbeing domains (the aforementioned four, plus emotional/mental wellbeing), assesses their interests and provides a coaching strategy through a tangible interface based on their status and interests.

The main goal is to generate and sustain motivation of older adults to take care of their health and to provide strategies to sustain healthy aging. For instance, the coach will suggest a personalized healthy diet as well as personalized physical, cognitive and social coaching, to prevent decline in these key domains and preserve wellbeing. In order to sustain motivation, NESTORE e-coach is designed as a friendly life-like companion that will guide the users to improve their wellbeing.

The *pathways of interest* are the key innovation element in NESTORE: we argue that such a system, able to provide personalized prompts and services according to the users' interests, can ensure that the overall wellbeing and health status is maximised. In this context, NESTORE aims at providing an innovative multi-domain intervention and at bridging domain experts' recommendation through novel and user-friendly interfaces, which are designed in order to support long-term use and self-reflection.

The paper is structured as follows: Section 2 describes previous e-coaching interventions promoting healthier lifestyles in older age; Section 3 describes the objectives and the challenges of the NESTORE project; Section 4 details the coaching strategy of the NESTORE system, explaining in particular the underlying behaviour change model, the domains tackled by the system, the concept of pathway of wellbeing, a subset of the proposed coaching activities and other design aspects of the interventions; Section 5 describes the system architecture and the main modules of the system; Section 6 discusses the results achieved so far and the still open challenges and Section 7 concludes the paper.

2 Related Work

Several interventions have been carried out to improve the wellbeing of older adults, both for prevention and rehabilitation. While traditional interventions required important human resources to carry out appropriate coaching and to guide the user towards the beneficial behaviour, modern technologies allow to automatise most of this process, reducing the cost of and democratising the access to such interventions.

Digital coaching, as recently defined by Banos and Nugent [4], implied "frequently, but not continuously, observe, listen to, question, understand, reason with, teach, and/or advise the users in order to change their behaviour and to improve their health". Digital coaches are often identified in the literature as virtual coaches or e-coaches. In NESTORE we would rather user the latter term, since, as will be explained in Section 4.6, one goal of the NESTORE project is materializing the digital system into a tangible companion that blends unobtrusively in the users' life. Since e-coaches aim at replacing human coaches, they need advanced features and intelligent behaviours. Kamphorst [13] resumed the following key features for e-coaching systems:

- *Social ability:* The coach should be able to engage in a conversation with the user.
- *Credibility:* The system has to be perceived as having expertise and being trustworthy.
- *Context-awareness:* The system needs to be aware of user context to propose ideas and actions that are relevant for the user.
- *Learning abilities:* The system needs the ability to ask questions, give feedback, and offer advice that is tailored to the individual user, building up and maintaining a personalized user model.
- *Data gathering:* The system will need to interface with different types of data streams (e.g., direct user input, but potentially also measurements of physical activities, mood self-reports, sleeping patterns), to provide individually tailored coaching.
- *Proactivity:* The system should initiate interactions with the aim of stimulating action.
- *Reflection:* The system should initiate interactions in a proactive manner, depending on user's sensed or predicted behaviour.
- *Behaviour Change Model (BCM) integration:* The system needs to know how a behaviour change trajectory looks like in order to provide successful coaching.
- *Planning suppor*t: To support users in setting themselves up for behaviour change success, the system should guide the user through the intention formation with appropriate planning strategies.

All these aspects are tackled in NESTORE through the e-coaching strategy and system architecture described in the following sections.

To understand how NESTORE relates to previous e-coaching interventions for promoting healthy lifestyles in older adults, we are conducting a systematic review (ongoing analysis). Our queries run on PubMed, EBSCO, Scopus and Web of Science allowed to identify 381 articles, of which 57 were retained for the analysis. Preliminary findings from the systematic review show that few interventions were designed in a multi-domain fashion, addressing all aspects of wellbeing (namely physical activity, nutrition, social integration, and cognitive functioning). Indeed, only the robotic companion Matilda [14] tackled all the domains, and only 9 of the 57 systems tackled more than 3 domains. NESTORE aims at dealing with all the aforementioned domains of wellbeing, providing tailored coaching in the first four domains, and additionally tackling the emotional domain for monitoring and building empathy with the user (see Section 4.2). In particular the multi-domain approach is designed using a novel integrated coaching strategy that we introduce in this paper: a multi-domain pathway to wellbeing (see Section 4.3).

NESTORE also proposes an innovative approach for promoting behaviour change, since it is based on a model specifically conceived for health interventions (see Section 4.1). In our systematic review, only 18 of the 57 explicitly adopted or discussed a conceptual behaviour change model guiding the design of the intervention. Only one study [18] in our systematic review adopted the Health Action Process Approach (HAPA) to design the e-coaching intervention strategy.

Transforming recommendations of BCMs into successful implementations of the e-coaching intervention is particularly challenging. In a scoping review on 27 studies, Lentferink et al. [15] analysed the key components that can significantly affect a variety of health outcomes, the adherence and the usability of an e-coaching intervention. The following BCTs were found to positively affect both health outcomes and usability in the studies reviewed:

- *Setting short-term goals to eventually reach long-term goals*
- *Personalization of goals*
- *Praise messages*
- *Reminders to input self-tracking data into the technology*
- *Use of validity-tested devices*
- *Integration of self-tracking and persuasive e-Coaching*
- *Provision of face-to-face instructions* during implementation, as key components for influencing both health outcomes and usability in a positive way

Moreover, the provision of personalized content was beneficial for both adherence and usability. These 8 key elements were often adopted in previous studies, although, from our analysis, no study adopted them all or did not report it. The most frequent intervention techniques applied in the studies were the personalization of goals and content, followed by using validity-tested devices and combining self-tracking and e-coaching. Praise messages and reminders were present in about a third of the studies while reduction of long-term goals to short-term goals and face-to face instructions were present in 9 and 15 studies, respectively. In NESTORE, we will pay particular attention to all 8 key elements as explained in the following sections.

3 NESTORE Challenges and Objectives

The target population of the NESTORE system are healthy older adults, with potential subjective feeling of decline in one or multiple key domains but without severe chronic pathologies. The target users are individuals with a good or high quality of life or lifestyle level, and NESTORE aims to encourage them to sustain their wellbeing in the long term. The coaching strategies called *pathways of interest* can be tailored and/or integrated into a single or multi-domain approach so to best fit with users' needs and preferences. Co-design is another key methodology: older adults and thus potential users of the NESTORE e-coach participated in the development of the system from the early stages of the project to maximise the matching of users' preferences and requirements. This is crucial but also very challenging, because the system requires the introduction of a very high level of modularity, customization capability and related complexity.

4 NESTORE Coaching Strategy

Promoting behaviour change requires taking into account several aspects, such as understanding psychological processes that can foster motivation, recommendations from domain experts for providing an effective intervention and user needs and preferences to obtain an enjoyable and sustainable experience. To this purpose, Section 4.1 will detail the BCM adopted in NESTORE and the related Behaviour Change Techniques (BCTs) that will be implemented. Section 4.2 describes the domains addressed by the NESTORE system for monitoring and coaching, while Section 4.4 details the coaching activities that the users can carry out in these domains. Section 4.3 presents the concept of pathway of wellbeing, explaining how this will be implemented in NESTORE. Finally, Section 4.5 and 4.6 discuss how NESTORE tries to increase the user experience and eventually the intervention effectiveness through a high level of personalization and a sense of companionship between the e-coach, physicalized in a tangible device, and the user.

4.1 BCM and BCTs

To guide the NESTORE coaching implementation, we used the Health Action Process Approach (HAPA) [23]) as theoretical framework of behaviour change (see also [6]). The advantage of the HAPA framework over alternative models of behaviour change is that it specifically focuses on two distinct phases (i.e., motivational and volitional phase) and consequently on phase-specific factors underlying the success or failure of the formation of an intention and eventually change in behaviour. In contrast to alternative models, it thereby also addresses the often-neglected intention-behaviour gap, meaning that some individuals may develop an intention to change their behaviour, but they might not act upon this intention. There are six key variables, which predict intention formation and change in behaviour. In the motivational phase, three variables predict if someone will form an intention to change their health behaviour: Risk awareness, which starts a process of critical reflexion, positive outcome expectancies and self-efficacy, which jointly operate to form the intention to change behaviour [24]. In the volitional phase, another set of three variables predicts how effectively the actual behaviour will be implemented by the individual: First, self-efficacy, as an indicator to overcome the intention-behaviour gap, which is also linked to how easily a person can get back on track after a relapse [22]. Second, action and coping planning, which denotes the when, where and how a target behaviour will be performed and how an individual will deal with potential problems arising when changing their health behaviour. And finally, action control, which subsumes self-monitoring and self-regulatory efforts when pursing a target behaviour. In orchestration, these six key variables determine whether or not a health behaviour can successfully be changed.

The NESTORE e-coach is a multi-domain coaching system, meaning that it offers older adults multiple coaching activities from various health domains (i.e., cognition, social activity, physical activity and nutrition). The NESTORE intervention is particularly challenging in terms of pursuing a behaviour change, as it may recommend the user to change more than one behaviour at once by engaging in multiple coaching activities simultaneously. Thus, it is crucial to implement a variety of behaviour change techniques (BCTs) to sustain the motivation of the user and promote the

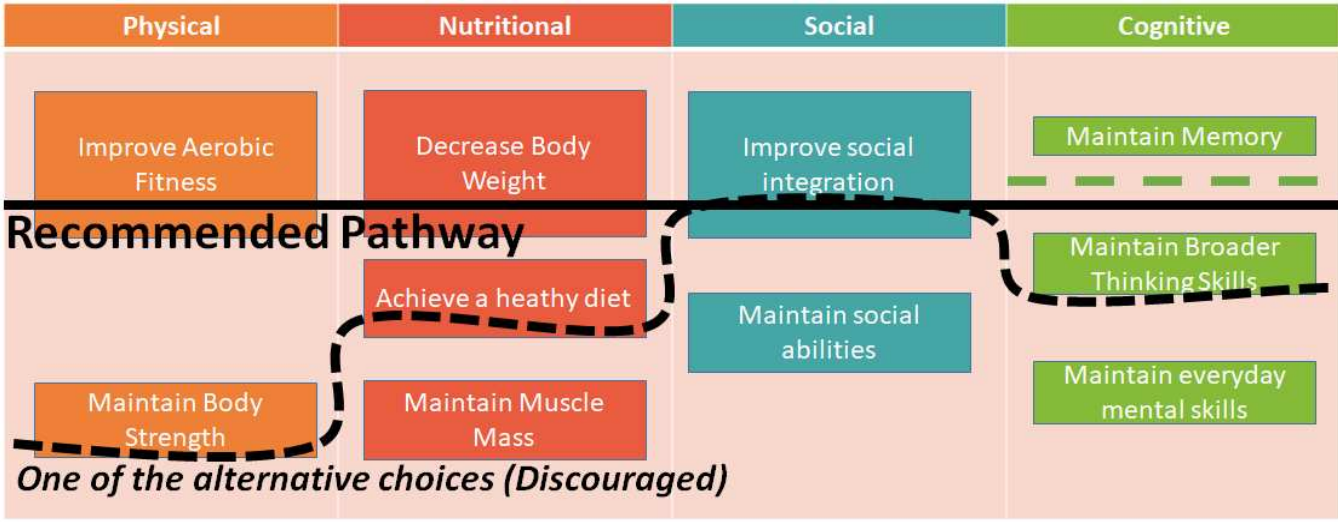

Figure 1: Example of a personalized pathway plan for a NESTORE user and two alternative choices that the user could make. The user would be recommended to take the straight pathway crossing all the domains that require more improvement, although she can still choose to go through other sub-domains (black curved dashed line). When the system determines that no training is needed in a domain, a shortcut (green dashed line) is available. If chosen, it allows skipping such domain. This is the case of the pathway on the straight line.

overall effectiveness of the intervention (e.g.,[2]). Based on a literature search identifying the most effective BCTs in the NESTORE domains, we will implement a variety of BCTs in the NESTORE coaching, including providing general educational information, providing information of health consequences, prompting intention formation, providing instructions, prompting specific goal setting and reviewing these behavioural goals, providing detailed feedback on health behaviours and many more. These messages will be personalized based on contextual and other person-specific information so that the BCT messages will come at the time and in the form needed by each individual (see also Nahum-Shani et al. [17]).

4.2 Tackling Multiple Domains

The coaching domains tackled by the NESTORE system are selected to improve or maintain the wellbeing of older adult users, counteracting the physiological and cognitive decline occurring with aging. They consist in physical activity, nutrition, cognition, social activity. The proposed approach is based on a holistic wellbeing model tailored to healthy older people [16].

4.2.1 Physical activity. The physical activity coaching is focused on four subparts: 1) aerobic training, consisting of structured activities, such as walking, running or cycling to improve cardiorespiratory fitness, 2) strength exercises, such as chair squats or knee push-up to improve upper and lower limbs strength and power, 3) flexibility training, using stretching exercise for upper and lower limbs to improve the body range of movement and 4) balance exercises, such as one leg stand or toe-to-line to improve the overall body stability.

4.2.2 Nutrition. The coaching plans for the nutrition domain are structured as follows: 1) body weight management, focused to increase or decrease body weight, and consisting of tailored dietary activities, as well as energy balance monitoring, 2) body composition management, focused to increase muscle mass or decrease body fat, and consisting as well of tailored dietary activities and energy balance monitoring, and 3) healthy diet, focused to improve their dietary habits by targeting macronutrients and micronutrients intake through both diet monitoring (based on automated food image recognition) and nutrition coaching.

4.2.3 Cognition. In the cognitive domain, we will provide the user with three possible coaching activities (see also [7]): 1) a cognitive training using a traditional, standardized working memory task to specifically enhance working memory (e.g., [11] [10]) a multi-domain cognitive training using a newly developed serious game based on previous research [5], incorporating tasks targeting multiple cognitive abilities to enhance broader thinking skills, and c) productive intellectual engagement intervention (i.e., cognitively challenging and stimulating activities; see e.g.,[20]) to enhance cognition in everyday life.

4.2.4 Social activity. In the social domain, we will provide the user with two possible coaching activities: 1) a social integration intervention to increase opportunities for social contact with like-minded peers (e.g., [21]), and 2) a social abilities intervention to enhance individuals' ability to function well in social interactions and social contexts (e.g., [9]).

4.3 Pathways of Wellbeing

The overall goal of NESTORE is to accompany older adults towards a healthier lifestyle. This is not possible without considering all the domains presented in Section 4.2. Identifying the optimal pathway for each individual is not trivial, and the role of the NESTORE e-coach is to guide the user in the choice of the appropriate *pathway to wellbeing* based on their status and interests. As informing the user in an intuitive manner on the goals and outcome of the intervention is crucial for adherence and engagement, we chose the metaphor of a pathway to represent the journey that each user should regularly go through, introducing healthy activities and behaviours into their daily routines. As wellbeing is intrinsically multi-domain, we represented a pathway as in Figure 1, encompassing the 4 domains presented in Section 4.2. Nevertheless, as every domain is intrinsically multifaceted and training in all aspects of wellbeing at once would be overwhelming for the user, we identified for each domain, different sub-domains that the user can choose from to build her own pathway and ultimately reach the goal of improving their wellbeing. These sub-domains mainly correspond to the different aspects elicited in Section 4.2, with the exception of the physical activity domain, where flexibility and balance exercises are integrated in both sub-domains for aerobic fitness and muscle strength.

After a period of two weeks in which the system monitors the user's habits, objective functioning and subjective feelings, the NESTORE e-coach will ask each user to build their own pathway to wellbeing, selecting for each domain one of the available sub-domains. The choice of the pathway at the end of the second week will influence the type of coaching activities that will be proposed to the user. These activities are described in Section 4.4. It is worth noting that the user will be informed about the kind of activities she will have to engage in for each sub-domain before committing to the chosen pathway. In order to increase her motivation, the user will repeat the goals she committed for in each sub-domain, signing a sort of behavioural contract.

In building the personalized pathway to wellbeing the role of the e-coach is crucial, since it guides the choice of the user towards a pathway that will likely most effectively lead to improvement of wellbeing. For this purpose, based on the information collected in the first two weeks, the e-coach will recommend sub-domains where the user needs more training to meet the domain recommendations elicited by experts. Therefore, a pathway will be customized for each user, including a recommendation whether an improvement is needed or whether maintaining the current level is sufficient. As such, using the metaphor of the pathway, sub-domains that more urgently need training will be depicted as larger roads.

Moreover, the e-coach will guide the choice of the user towards sub-domains from different domains that share overlapping features, so that synergies can be built to increase the effectiveness of the intervention. For example, combining exercises for muscle strength with recommendations for protein intake are assumed to be more effective than the respective interventions alone. Back to the pathway metaphor, sub-domains sharing overlapping features will be aligned in the interface, suggesting that taking a straight pathway will be more effectively for an improvement of the wellbeing.

Finally, to limit the user-burden to train concurrently in multiple domains, the system may allow the user to take shortcuts and skip the domains that do not need particular changes in behaviour to maintain the current level. In Figure 1, we represented a shortcut in the cognitive domain with a dashed line.

4.4 Coaching Activities

A three-layer system is proposed in NESTORE to adapt better to users' needs and interests. This layered system allows users to 1) select a pathway to follow (as described in Section 4.3); 2) choose how they want to achieve that goal, henceforth referred to as coaching activity plans (CAPs); and 3) accomplish their goal by executing specific coaching activities scheduled by the system, named coaching events (CEs). Here we can see as the overall goal of improving the wellbeing is first reduced to specific goals in each domain (the sub-pathways) and then to elementary activities that the user should carry out during their daily routines. These three layers are consecutively dependent on each other: a pathway contains many CAPs, and a CAP is formed by many CEs.

4.4.1 Example of a coaching activity plan for physical activity. If a user, for example, receives the recommendation or chooses to perform aerobic training, she/he can choose among three different schedules: three, five or seven sessions per week; moreover, the user can select exercise intensity (light, moderate or vigorous). Based on these choices, the system provides the user with her/his personalized training plan (75-300 minutes per week depending of the selected intensity), putting the physical activity sessions into the user's weekly calendar and encouraging her/him to adhere to the plan. Each training session is monitored using a wearable device able to measure heart rate, physiological variables needed to understand the user's effort and for providing prompt feedbacks to the user. In order to reduce the workload from carrying out structured training sessions, the NESTORE system also measures, by the wearable device, the activities performed by the user during her/his everyday life and adapts the physical activity training plan accordingly, reducing the time to be dedicated to the structured training sessions.

4.4.2 Example of a coaching activity plan for nutrition. If a user for example chooses or receives the recommendation to increase muscle mass, the system provides her with personalized dietary activities based on personal food preferences and especially designed to favour muscle mass accretion, by targeting mainly protein and total energy intake. Some examples are "Add pumpkin seeds to salads" or "Choose nuts as a snack". Moreover, users are asked to monitor their dietary intake during at least 3 days per week (including one weekend day) by taking pictures of all their meals with the mobile phone. The system returns their daily and weekly energy and nutrient intake, and shows them if they are within, below or above the recommended ranges. Energy expenditure is

monitored by using a wearable device, and displayed to the user in order to help him/her getting a positive energy balance, essential to achieve an increase of muscle mass.

4.4.3 Example of a coaching activity plan for cognition. If a user for example chooses or receives the recommendation to engage in the serious game activity, they will be asked to engage in this activity 5 times per week for approximately 30 minutes, resulting in 2.5 hours of cognitive engagement per week. This person will be asked to manually navigate a boat along a memorized path through a natural reservoir, while reacting to certain stimuli and inhibiting their reaction to other stimuli. Thus, three cognitive abilities will be incorporated in the serious game task: inhibition, spatial memory and visuo-spatial coordination (adapted from Binder et al. [5]). The serious game will also be adaptive in nature, meaning that the difficulty level increases (or decreases) if the performance of the user increases (or decreases). Adherence will be monitored and data will be stored in the system.

4.4.4 Example of a coaching activity plan for social activity. If a user for example chooses or receives the recommendation to engage in the social integration intervention, they will be asked to engage in this activity approximately once per week for 1-2 hours. The user may choose form a variety of provided suggestions on how to engage in social opportunities, such as joining a theatre club, orchestra, choir, group sport, or senior citizen activity. The NESTORE system will provide information on where to find these activities in the area of the user. Some of these activities may also involve cognitive or physical elements to facilitate cross-domain pathways.

4.5 Personalization

NESTORE deploys several tools towards fostering the adoption of wellbeing of older people. However, the success of the mechanisms designed throughout the different modules of the system greatly depends on the users' engagement with the platform and, more specifically, with the degree of personalization of those mechanisms. Thus, it is clear that regardless of having a good design of BCTs, NESTORE will not be able to trigger any effect on users' health and behaviours if they do not feel engaged and get some sense of real support from the system. In this regard, what should be avoided is user burnout and immunization to the interactions, which could be caused by either non-personalised recommendations or out-of-context interventions. Therefore, what NESTORE aims to achieve is an emotional link between users and the platform, making the users feel supported by the e-Coach whenever they need it, in an appropriate format and in a personalised manner. For such purpose, knowledge processing algorithms and reasoning techniques are included so that, for instance, coaching plans can be personalised in terms of which kind of coaching activities are proposed, when they are sent –frequency, time of day, etc.-, the total amount of recommendations to administer and their priority**.** For example, the status of the user on the different target domains or the weather and temperature are items that will have an impact on the coaching plan proposal and its personalization.

Users have multiple possibilities for choice, starting from the choice of the pathway, as described in Section 4.2, which will affect the sub-domains that they will train and the types of coaching they can engage on. Depending on the domain, the user will also have the possibility to choose among different coaching activities for achieving the same goal.

In general, the system is also tailored for older adults of four different countries which participated in the co-design process, namely the UK, The Netherlands, Spain and Italy [CHI paper]. This will result not only in an interface translated in the four respective languages, but also in conversation tailored to the local habits and traditions, as well in social activities that are linked to the local facilities and events.

In particular, the coaching activities that will be implemented in the system reflect the interest of the users, collected in the four countries, first through co-design workshops and then through a survey. Whenever possible and within the terms agreed by domain experts, user feedback is also employed to adapt the amount of training that the e-coach should propose, according to how much time the users think that they can reasonably spent to engage in coaching activities.

4.6 NESTORE e-Coach as a Companion

As anticipated in Section 4.5, a key goal of the NESTORE e-Coach is also to build an empathic relationship with the user, in order to increase trust in the system and to foster adherence to the proposed intervention. In order to avoid a distant e-coach that is perceived as a mere virtual entity, the e-coach will be embodied in a tangible artefact, which is still undergoing a co-design process [8]. The tangible coach will allow users to interact through voice and lights, constituting a daily companion that might encourage people to engage in the NESTORE intervention. This tangible artefact will also help to build an emotional relationship with the user and, to this purpose, one of its goals is understanding users' emotions. Indeed, in order to build empathy with the user, the system will ask the user to report about her day and a semantic analysis of its corresponding response will allow the e-coach to detect the emotions felt by the user and to respond accordingly. As mentioned already in Section 4.2, it is worth noting that no specific e-coaching intervention will be provided directly for the emotional and mental wellbeing. Physical interactions will be also implemented, such as touching the tangible coach in order to enable vocal communication or changing the position and orientation of the tangible coach to change the interaction modality of the coach. This should foster further the emotional bonding between the e-coach and the user.

As the interface of the tangible coach may be limited in terms of type of content that can be delivered and not adequate for all situations, different interfaces will be available to ensure a proper communication between the user and the e-coach, typically available on the user's smartphone. The e-coach will then continue interacting with the user in a more virtualized manner through the different interfaces, namely, an app with integrated chatbot, a game and a wearable. These interfaces are detailed in Section 5.3.

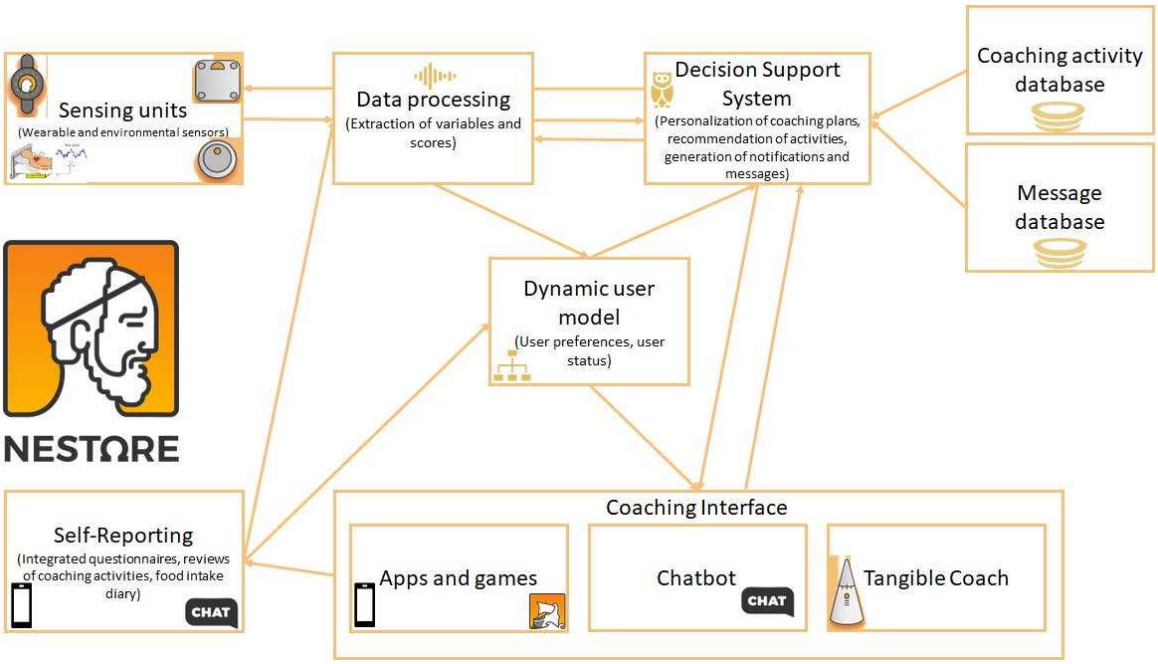

Figure 2: NESTORE e-Coaching architecture.

5 E-coaching System Architecture

Ochoa and Gutierrez [19] identified a typical architecture for e-coaching systems. The key elements of the proposed architecture can be categorized in (1) data gathering, (2) data processing (which includes sensor data analysis and decision making for adapting the intervention to the context) and (3) actuation of the intervention through the delivery of the coaching action to the user. Data analysis includes both the understanding of user variables and characteristics (i.e., monitoring unit) and user actions (i.e., diagnosing unit). In particular, the intelligence of the system (i.e., learning unit) should be able to adapt the intervention according to different contexts: the state of users' characteristics, the user model (including users' preferences), the coaching plan and the progress throughout the coaching plan. Figure 2 depicts the e-coaching architecture of the NESTORE system. In the following subsections, we detail each part of the e-coaching system.

5.1 Data Gathering

Data gathering in NESTORE is supported by both sensors and self-reporting interfaces. Monitoring of physical activity is supported by a custom wearable device, a bracelet co-designed with NESTORE users, able to measure heart rate and physical activity levels, targeting in particular the aerobic fitness sub-domain. It is also equipped with a beacon receiver for the detection of daily activities and social exchanges with family and friends, which may wear themselves a beacon as a sign of support for the older family member. The sensor set also includes a bed sleep monitor and a smart scale with body composition analysis. Cognitive games and exercises integrated in the app allow to monitor user's memory and broader cognitive functioning.

It is worth noting that most domains require also self-reporting in order to accurately monitor user status, which is important for providing tailored coaching, as described in previous sections. In particular, food intake can be monitored both through an app and through a conversational agent. The Logmeal food recognition API [3] is used to support the user in food tracking, allowing the user to track food by simply sending a photo to the e-coach, through the chatbot or through the app. The e-coach also periodically asks questionnaires about daily social engagement, perceived loneliness and cognitive behaviours in daily routines. These standardized questionnaires are presented through the chatbot or the app in order to speed up the process and increase the user experience and engagement with the coach. Emotions and stress are tracked both through questionnaires and through semantic analysis of user's answers to selected questions with the conversational agent. The analysis is performed through an adapted version of the EMOTIVE ontological model [25].

5.2 Processing

NESTORE personalization techniques are encompassed inside a Decision Support System which is the core component that provides intelligence to NESTORE modules and adequate the interactions to users' preferences, status and context.

A decision support system (DSS) can be defined as a "computerized information system used to support decision-making in which the characteristics of an individual are matched to a computerized knowledge base [12]. A DSS lets users sift through and analyse massive reams of data and compile information that can be used to solve problems and make better decisions.

In NESTORE, the DSS is intended to help older adults to compile useful information about their lifestyle in order to identify proper actions and make decisions to improve or maintain a healthy life.
In order to achieve this, data mining algorithms are used for modelling the user behaviour in a short-term timespan and then providing support to the user to decide the most convenient coaching activities based on the implementation of a tagging system and other reasoning techniques. NESTORE data processing is based on various techniques used to model and personalize the recommendations. First, a dynamic user profile is built –including either sensed, inferred or manually inputted data and user context - , then, different reasoning systems are applied to make personalised recommendations on the pathways and coaching activity plans.

5.3 Intervention Delivery

Following the recommendation of the decision support system, coaching is provided to the user through different interfaces, implementing each different BCTs. The different interfaces can also be used in different interaction contexts.
The main intervention is provided through a smartphone app, developed with the Ionic cross-platform framework. The app allows to self-monitor progress in the different domains as well as to schedule activities in a calendar view. It also allows to report food intake and to invite people to join coaching activities that she scheduled in the calendar. Through the same app, users can also chat with the e-coach, which will provide educational content, instructions for coaching activities, reminders, praise messages and will ask questions to the users, for self-monitoring purposes (as discussed in Section 5.2). The chatbot can also be used to report food intake. The chatbot has been developed with RASA NLU, which enables intent recognition and context management [8].
The smartphone can further be used to play games, which will target the physical, cognitive and social domains. As support for physical activity, the wearable device will also provide specific feedback on physical activity intensity level. Moreover, a social platform allows to access local events and to invite people (e.g., friends or other NESTORE users) to coaching activities, providing social support for succeeding in the personalized pathway to wellbeing. Finally, a tangible device will embody the e-coach, providing advices and allowing to engage in richer conversations, eventually touching the emotional sphere of the user.

6 Discussion and Future Work

The NESTORE e-coaching intervention was designed to implement all the features elicited by Kamphorst [13]. Indeed, for the *social ability* of the e-coach, as discussed in Section 4.6, a conversational agent supports both text based and voice-based conversations. Moreover, to increase the user experience of such conversations, user's affect is assessed in order to build empathy with the user. The *credibility* of the system is ensured by the recommendation of experts in the different domains, which designed coaching activities based on previous empirical evidence. In the onboarding phase, such scientific underpinning will be highlighted. Moreover, informational messages could be supported by scientific facts for people interested in the additional science behind the project. In general, information material on the scientific background of the project will be provided in the NESTORE web site as additional source of reference for the users. For *context-awareness*, adapting and suggesting appropriate coaching activities is one of the main goals of the decision support system. As described in Section 4.5, coaching activities are suggested and adapted not only according to the user's state and preferences but also according to context information, such us weather condition, or proximity to local facilities. Concerning NESTORE e-coach *learning abilities*, a dynamic model is built that stores users' system preferences but also preferences related to coaching activities. In particular, the selection of coaching activities among the provided list as well as the user's rating at the end of the activity are used to continuously improve user recommendations. As explained in Section 5.1, *data gathering* is ensured by wearable and environmental sensors, as well as from self-reporting by users in the different interfaces. *Proactivity* is another feature that NESTORE can boast: the system initiates interactions by means of reminders and notifications, based on the integrated HAPA model, in order to stimulate and motivate the user to commit to the chosen pathway. However, frequency of system prompts can be configured to some degree by the user in order to adapt to personal needs and time availability. A key goal of the NESTORE system is also to stimulate *reflection* on the impact of lifestyle choice thanks to educational messages. Self-reflection is also stimulated through self-monitoring and in particular through tangible ambient displays that reflect users' progress in the pathway. As discussed in Section 4.1, the HAPA *behaviour change model* has been integrated in the system in order to deliver the different interventions in a time-appropriate manner. Finally, as a tool to provide appropriate *planning support*, the e-coach allows to schedule activities in the calendar, adapting to user preferences and availabilities.
A remaining challenge for the NESTORE project is to provide an intervention that fits users' expectations and the users' ability to deal with a complex intervention and with a complex system. Indeed, a multi-domain intervention is ecologically valid and reflects the multidimensionality of wellbeing and health, but at the same time might overwhelm the user if not accurately planned and adapted to the user preferences and time availability. At the same time, the complexity of the system, composed by several devices and interfaces, has to be hidden behind a user-friendly interface. From this point of view, the e-coach has to guide the user not only through the pathway of wellbeing, but also through a series of technological tools that will support the users all along their path.
Therefore, to check overall feasibility of the NESTORE coaching, and to specifically assess usability and effectiveness of the NESTORE coaching activities, we will conduct a randomized controlled pre-test/post-test pilot study. Users will randomly be assigned to a group receiving the technology-based personalized NESTORE health coaching intervention (experimental group; N = 60) or to a group that receives a standard non-personalized health intervention (control group; N = 30). Data collection will start in fall 2019 and be finished in spring 2020. The pilot study will consist of six distinct phases:

1) *Pre-test assessment*: Collection of impact variables for usability and effectiveness evaluation
2) *Setup and training*: Installing of the system and accustoming of the user with the system
3) *Pre-intervention tracking*: Collecting single-time system-based assessment of variable packages and daily live tracking of variables relevant for the DSS and effectiveness evaluation

4) *Coaching phase*: Engagement in the selected and recommended coaching activities and exposure to the BCTs.
5) *Post-intervention tracking*: Collecting single-time system-based assessment relevant for effectiveness evaluation
6) *Post-test assessment*: Collection of impact variables for usability and effectiveness evaluation

In terms of usability, we will assess the particular experiences of the users with the NESTORE system, including the quality, reliability, and acceptance of and interaction with the technological system. In terms of effectiveness, the main goal of the pilot study is to investigate differences between the experimental and control group in selected key variables in all four NESTORE domains (cognition, social activity, physical activity and nutrition) and overall indicators of health and wellbeing, such as life satisfaction and aging satisfaction, between pre- and post- intervention occasions.

7 Conclusion

This paper presented NESTORE, an e-coaching intervention for promoting healthy lifestyles in older age. In the article we highlighted the novel approach for providing simultaneous coaching activities in different domains, modelled as a personalized pathway towards wellbeing. We showed how the design of e-coaching system was based on state of the art recommendations for e-coaching systems, as well as on the HAPA model for behaviour change as conceptual underpinning. We highlighted the importance of designing an e-coach which is not only a tool for exercising but also a companion of the user during the process of behaviour change, providing support and knowledge for sustainable and long-term wellbeing improvement. Finally, we discussed the open challenges of the NESTORE project, highlighting that, despite of the fact that the system was co-designed with older adults throughout an extensive process, only the pilot studies that will be conducted in the next months may be able to tell if the proposed e-coaching intervention will fit users' expectations and will succeed in changing the users' behaviour towards healthier lifestyles and thus have beneficial effects on target outcome variables.

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